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(54) Abstract Title
Making a pig

(57) An integral pipeline pig construction comprising an alternating series of body discs 120 of polymeric material and body tori 112 of softer foamed polymeric material coaxial on a central core 124 is made by providing a plurality of the foam tori 112 in a stack in concentric spaced relation, passing material for moulding the discs and central core through and between the tori, and allowing the moulding material to harden. Preferably, adjustable diameter individual straps 132 are used to space the stack of tori and to define the diameter of the discs 120. A method of pigging a shoreline using a foam pig is also disclosed.

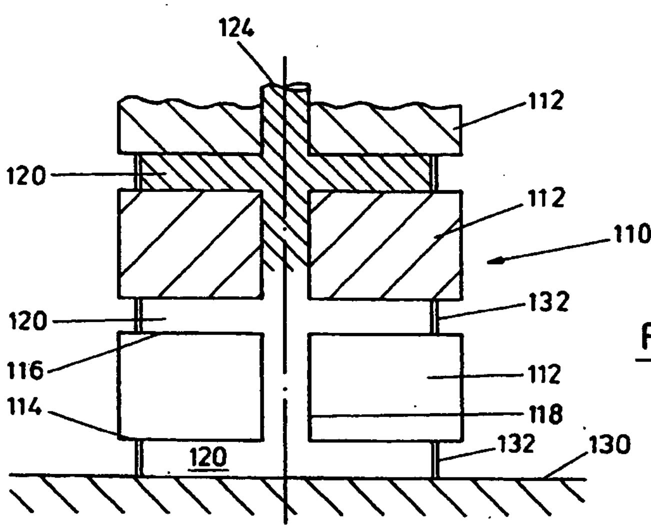

FIG. 7

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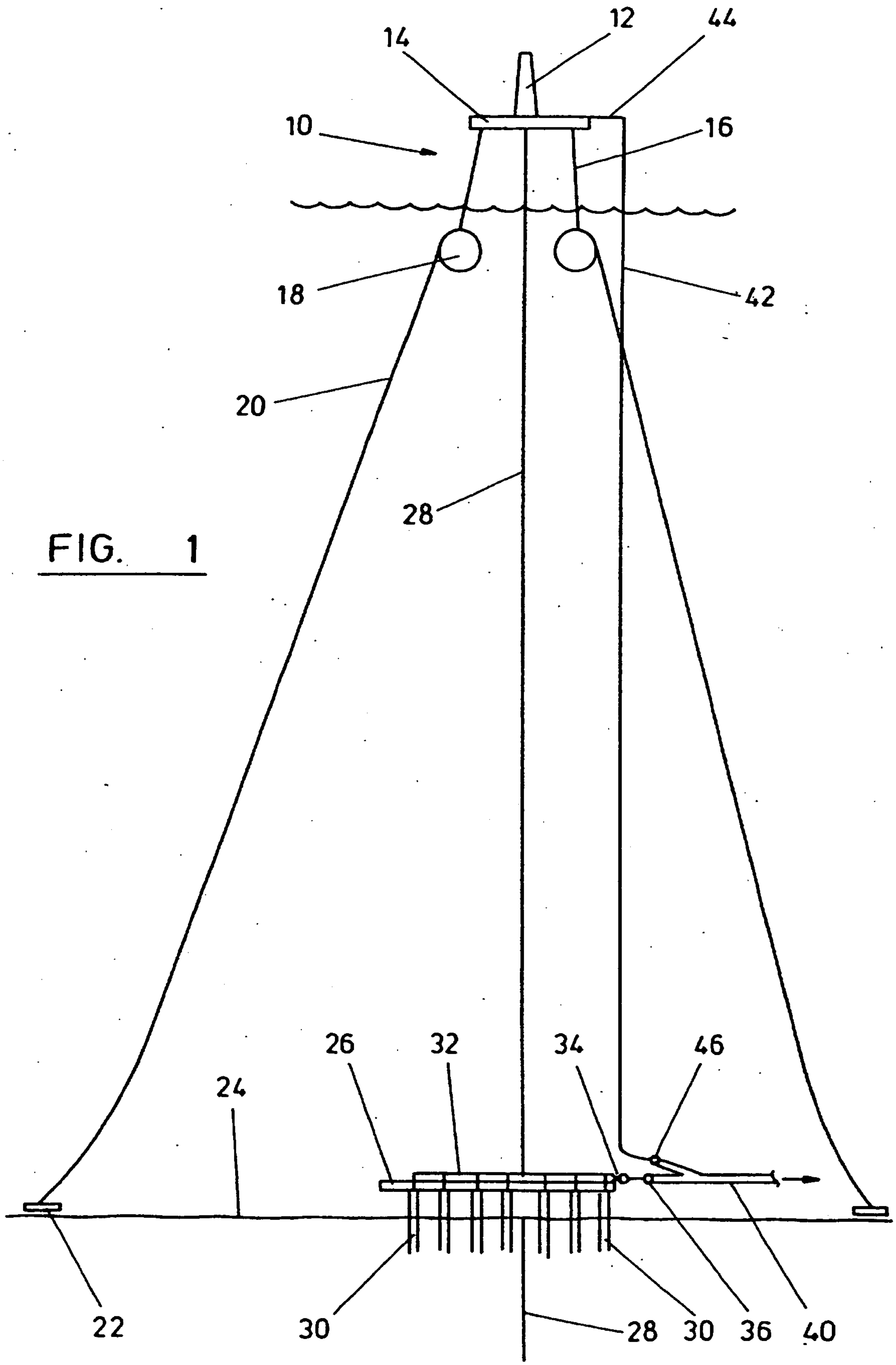

FIG. 1

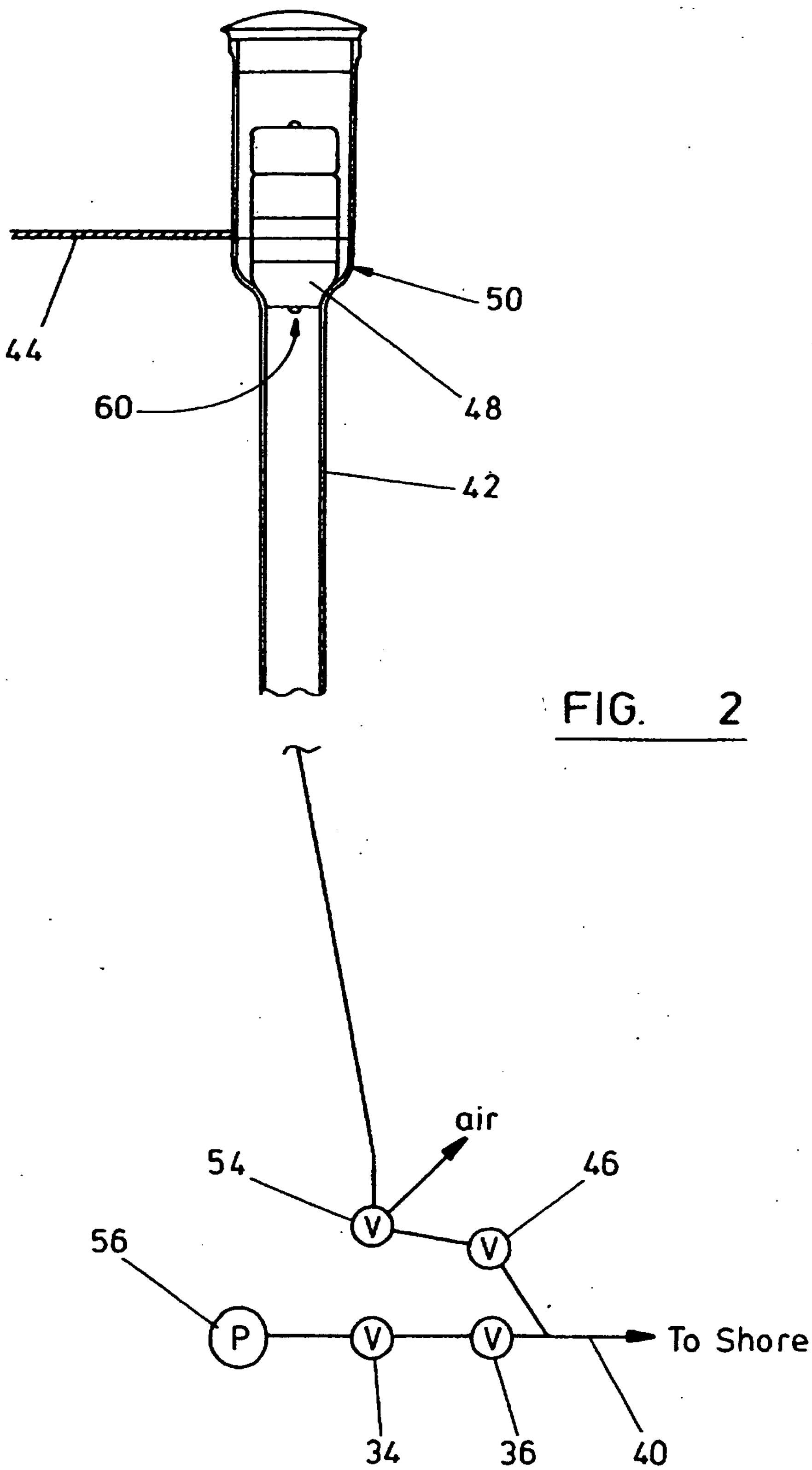

FIG. 2

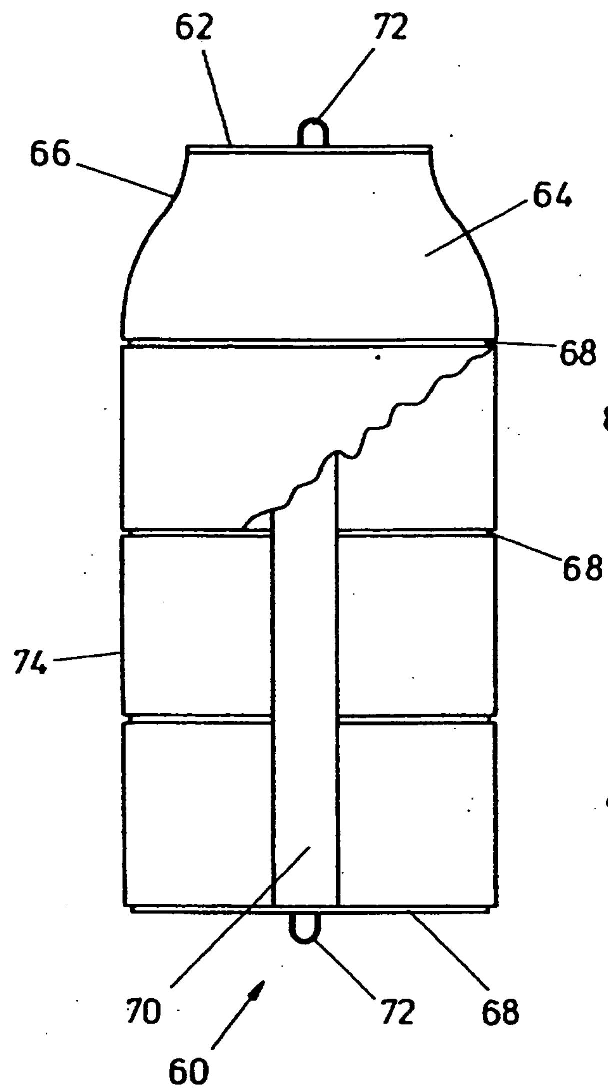

FIG. 3

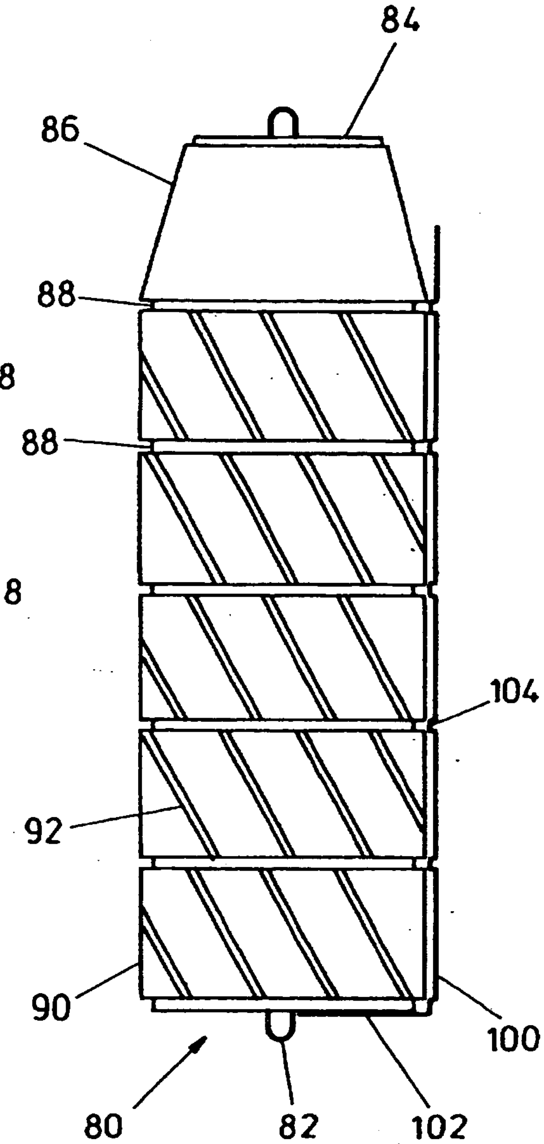

FIG. 4

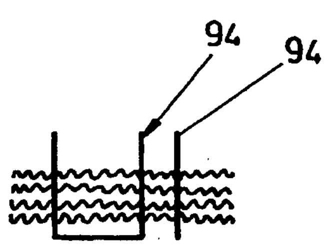

FIG. 5

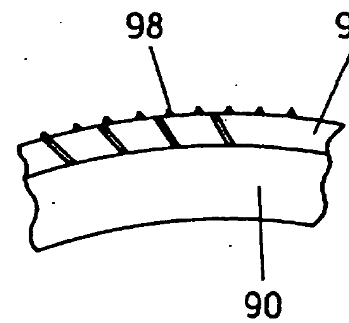

FIG. 6

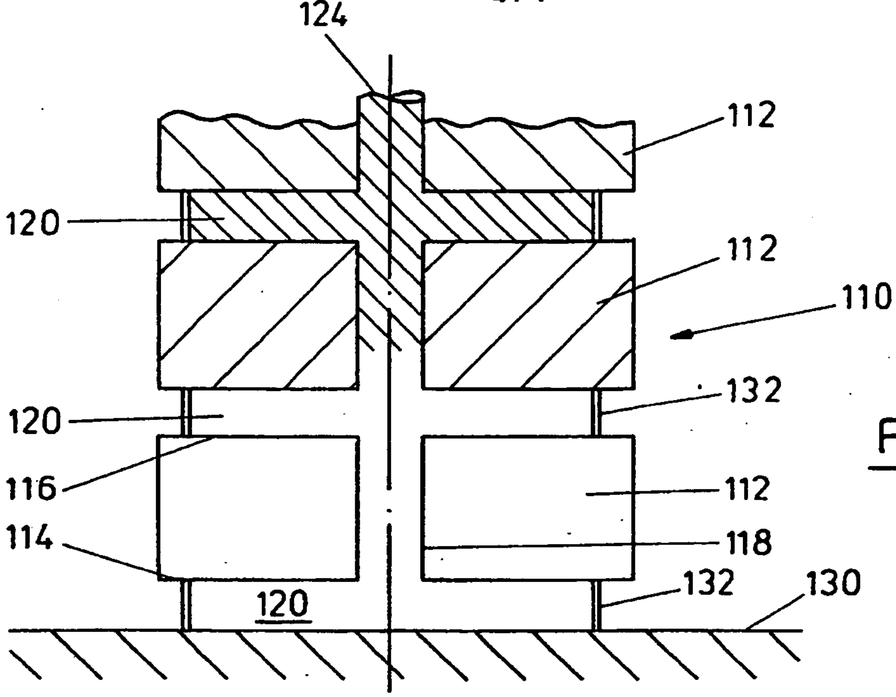

FIG. 7

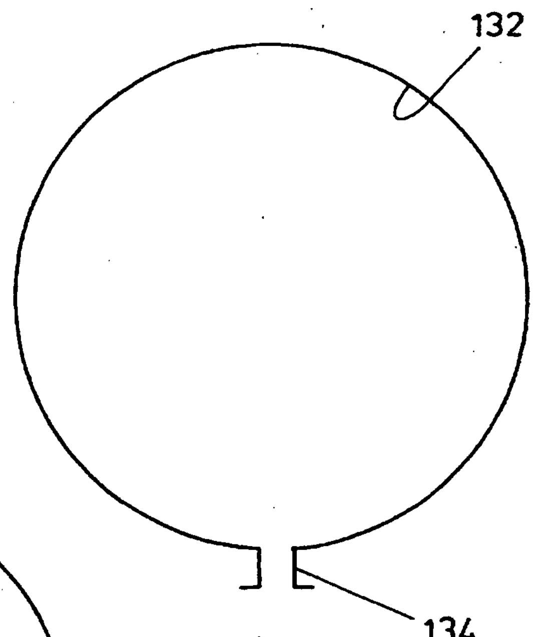

FIG. 8

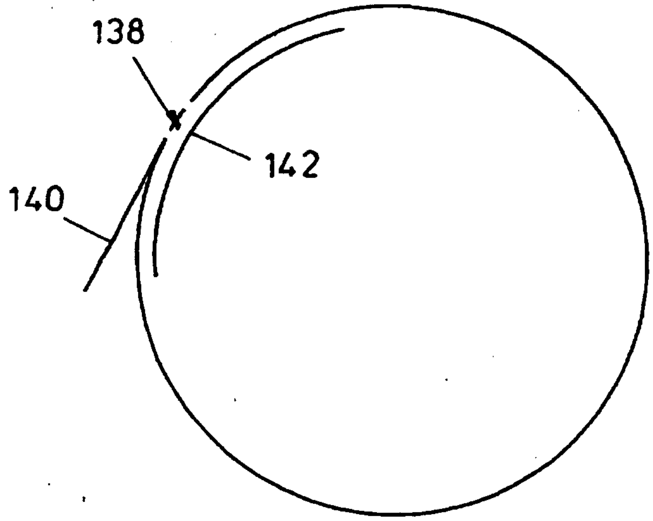

FIG. 9

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METHOD AND APPARATUS FOR MAKING A PIG IN A VERTICAL RISER PIPE

Pipeline pigs are extremely helpful in the operation of pipelines. Ordinarily, pipelines extend cross country, typically placed on the surface, but sometimes they extend under bodies of water. They can cross rivers and lakes. It's not uncommon for pipelines to pass under several bodies of water. In offshore circumstances, pipelines extend from production platforms perhaps 50 to 100 miles out in the Gulf of Mexico. Typically, the water is relatively shallow. In many places, the water is only about 100 feet deep even when the production platform is many miles offshore. In those instances, the platforms are fixed structures supported on the bottom. In deeper waters, platform erection costs become prohibitive. While two or three large platforms have been erected or perhaps have proceeded to the planning stage, it appears that the maximum limit for stationary construction of a platform is about 1,200 feet of water. Such platforms are extraordinarily expensive in that they require the frame structure as large as any of the tall buildings in the U.S. They

are erected on shore and towed to an offshore location. They are deployed only when the production platform is known to be above a very prolific and highly productive field. A better approach now is the use of a tension leg platform. A tension leg platform involves a platform which is made with adequate buoyancy that it will float and hold the working deck properly above the wave action. It is held in place by cables which extend to the bottom and are anchored at the bottom. The buoyant body is held on flexible lines which are maintained in tension. It resembles a buoy which is anchored by multiple anchor lines extending to the bottom. This reduces markedly the amount of structural steel and the assembly required to assemble that structure into a supportive rigid framework. The tension legs are deployed around the platform and are anchored at the bottom.

The typical platform installed at offshore locations supports a complex amount of equipment on the deck for actual production. Indeed, the production platform may also temporarily support a drilling rig while the last of several wells are drilled. Ordinarily, a platform will not be installed unless several wells are serviced from the platform. While the number can be varied, it is not uncommon to terminate 30 to 50 wells serviced from a single platform. Many of the wells are deviated so that they actually reach bottom depth at desired locations scattered over a producing formation so that optimum production can be obtained. All the wells are therefore

connected to the platform and are operated from the platform. Wellhead equipment (such as the Christmas tree) and surface gathering lines associated with land wells are not always placed on the production platform. It is desirable that wellhead equipment be located at the mudline. Typically, the wells incorporate conductor pipes to a mat or template which supports the casing and pipe strings. The many wells are terminated at the wellhead equipment located underwater. Producing wells are connected with a manifold to deliver the produced fluid and that in turn is directed into a flow line from the underwater template toward shore.

To make the example specific, assume that 40 completed wells terminate at the underwater template. Each well is provided with appropriate wellhead equipment. Wellhead valves direct their flow into a gathering line. Assume that the gathering line is a 16 inch line located in 1,000 feet of water. The gathering line delivers, under pressure, the produced oil which is pumped into the gathering line and flows to a shore location where the line emerges from the ocean. Assume that the gathering line is 200 miles long. The 200 miles of gathering line is exposed to cumulative collection of materials from the flowing oil. The materials in the gathering line often will coat the inside of the gathering line. Pipe coating is primarily dependent on the nature of the production and the temperature of the production fluids. If, for instance, the production fluids are extremely hot when produced, they will be cooled significantly in transit along the 200

mile gathering line. As cooling occurs, heavier molecules tend to coat on the pipe. It is possible that the inside diameter of the pipe will be markedly reduced by the cooling of the produced well fluids.

Sometimes, a producing well will produce small or great quantities of water which is laden with insoluble constituents. Again, the nature of the constituents will vary widely. It is however possible that they also will go out of solution and thereby plate the inside wall of the pipe. It is not uncommon for the gathering line to require cleaning periodically. Cleaning of the gathering line requires insertion of a pipeline pig into the gathering line. The pig is forced by the fluid flow from the underwater wellhead to the far end of the gathering line where it emerges onshore. In this particular instance, the gathering line must be pigged so that optimum production can be continued. If pigging is neglected, it is conceivable that the gathering line will become smaller and smaller in effective flow volume. Ultimately, serious problems can arise when the gathering line is severely plugged. It is not uncommon for the hardened materials which collect against the wall to reduce effective cross-sectional flow area by 50%. Because of that, pigging is absolutely essential to clean the line. A pig launcher is ordinarily used for lines onshore. In this instance, the pig launcher is not normally installed underwater. A vertical riser pipe is used for the pig launcher. The vertical riser must stand taller than the depth of water in which the wells are located. If the wellhead equipment is located at a depth of 1,000

feet, then the riser pipe must be 1,000 feet in height, and must have sufficient additional height so that the open end will not take any water. It is necessary to extend the pipe about 60 feet taller than the normal depth of the ocean. This vertical riser is 1,060 feet in height. This vertical gathering line riser is unwieldy. It must be stabilized laterally. Otherwise, ocean currents will force it to the side. It is sufficiently unstable in light of its relative height that it would otherwise topple. It is, however, tied to the platform above. This will add stability at the upper end so that the riser pipe will not fall over or be deflected by ocean currents or wave action.

With jack-up drilling rigs, no problem arises because the weight of the drilling rig is supported on the ocean bottom. With fixed platforms, weight does not pose a problem either because the weight is supported on the legs. With a tension leg platform, weight becomes a problem if it is excessive. In this particular instance, the gathering line riser poses a problem because it is heavy and it connects with the platform at one edge. Again, the offset point of connection would not be a problem with a fixed platform. Here, the point of connection becomes a problem because that amount of weight at one side tends to tilt the platform because it is a floating platform. Because the platform is floating, both the weight and offset connection of the riser becomes a serious problem.

One way to overcome this is to reduce the diameter of the riser. Another weight reduction is to reduce the wall thickness. Wall

thickness, however, is mandated by the depth of the water. If production is large, then a larger diameter gathering line is services by a larger diameter riser.

The present disclosure sets forth an improved system for gathering line pigging where the pig must be inserted through a vertical riser of several hundred feet in height. It sets forth a pig construction which is passes downwardly through the riser and then finally into the gathering line. If the vertical riser is reduced in diameter and wall thickness, a substantial reduction in weight occurs. In turn, a reduction in diameter of the riser requires a different pig construction. Therefore, another aspect of the present disclosure sets forth a different type pig. In particular, this pig is constructed to work with a bell receptacle or nipple at the top end of the riser. The pig is dropped into the riser, and lands in the bell. By gravity, it is caused to fall into the riser. Ultimately, it turns to the horizontal into the gathering line. The pig is used time and again until it is finally worn out.

The present disclosure thus describes both a riser pipe construction and a pig construction so that the pipe is made as light as possible, the pig is readily inserted, and yet the pig is permitted to shrink and then expand for actual transit through the producing line.

The present disclosure also sets forth an improved pig which is able to travel in both directions in a pipeline. For a pigging operation, removal and reversal of the pig can be done easily if there

is a trap for the pig and if the pig is relatively small. When the pig is up to 12 or 16" in diameter, it can be handled easily. That is not so for a large pig. For instance, a pig measuring 24, 30 or 36" in diameter cannot be pulled easily from a pig trap, reversed and reinserted for launching in a pipeline. It is necessary in many instances for a pig to travel in a bidirectional fashion. For instance, the pig may be launched from one location, sent to another location a few hundred feet or a few miles away, and then returned to the first location by reversing the flow. Pig travel in the pipe runs the risk of leakage around the pig. Leakage occurs as a result of flow by. There is another problem in handling the pig at the time of reversal. When the pig is exceedingly large and cannot be pulled from a pig trap and relaunched after reversal, it is important to have a pig that can run in both directions. Pigs made with cups simply cannot do this. Pigs made with discs can do this provided the cups do not deform. It is necessary to therefore flip the disc. By that, the bow in the disc must be reversed. So to speak, the frictional drag around the lip of the disc causes the surrounding edge to drag and fall behind the pig body. At the end of the line where a reversal in direction is required, the pig disc must snap, i.e., it must reverse or flip the peripheral edge to a trailing position. That is not easily accomplished in pigs. The present disclosure sets forth a pig which can accommodate these requirements. It is a pig which provides quality sealing in a pipeline. More than that, it is a bidirectional pig which is

able to reverse movement without requiring intervention. The pig is simply reversed in its direction of movement and the discs in the pig are reversed. Such reversal is accomplished by the present pig taking into account the alternating hard and soft portions thereof. This pig construction enables reversal easily so that subsequent pig travel in the pipeline is readily done without difficulty.

In one aspect of the present disclosure, the pig is a two part polymeric foam system. The bulk or body of the pig is made of a soft foam. Several discs are integrally constructed along with a central core and they are made of a harder polymeric material. By forming the pig in alternate layers, improved sealing characteristics are obtained and the pig is able to flip, i.e., to move the peripheral edge to a trailing position with respect to the central core of the pig when reversed movement occurs.

In one aspect of the present disclosure, the pig is constructed so that there is better bonding of the components of the pig. One component is made of a light foam and is positioned adjacent to and serves as a mold piece for a heavier disc material. As the mold for the heavier material, better bonding is obtained between the two types of materials. This assures that the pig is able to hold together in a better fashion. This prevents breaking apart at the interface between different types of materials.

Common flow lines are found at 2" intervals. Therefore, beginning at 4", the nominal sizes of a set of pigs of a particular

design should encompass the diameters of 4, 6, 8, 10, 12, etc. These measurements in inches again are the representative or nominal diameters. While the precise diameter or I.D. of the pipe may vary somewhat from the nominally stated dimension, the germane point of this discussion is that there is a required mold for each and every size. The molds become more expensive at greater sizes while the number of larger size pigs sold are reduced. Restated, there is simply a greater installed mileage base of pipelines measuring 12" and 16" compared to 32" or 36". To be sure, 36" pipelines exist but they require a mold which is much larger, they involve handling of much greater weights in molding and after molding and the unit sales do not correspond with the increased size of pipe diameter. Again, the most common pig sizes sold are typically 8, 12 and 16". The greater mileage of pipe of these dimensions requires a larger number of pigs of these sizes.

With the advent of this new type pig, capitalization cost must encompass the cost of making the molds. This can easily require a dozen molds to offer to the trade the different sizes of a newly devised pig. The present disclosure is directed to a method and apparatus for molding pigs which reduces the mold cost significantly. Indeed, through the present disclosure, pig cost can be significantly reduced and the capitalization cost can be reduced even more. This reduces storage space required for molds when not in use, and also reduces significantly the difficulties of handling such molds. As will

be understood, a metal mold for making a 36" pig is quite heavy. In effect, it resembles a very large, heavy metal barrel and has to be handled with overhead hoists.

The present disclosure is therefore summarized as an improved method of manufacture of a molded pig formed of two parts or types of material. They are assembled by cutting donuts from a solid foam cylinder made of a very light weight foam. By use of surrounding straps, several donuts are joined in a single pour which defines the axial core and discs at spaced locations including the two ends of the pig. The several discs are defined at the same diameter to enable quality sealing in a pipe.

So that the manner in which the above recited features, advantages and objects of the present invention are attained and can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to the embodiments thereof which are illustrated in the appended drawings.

Fig. 1 is a schematic showing a tension leg platform above a template on the ocean bottom supporting wellhead equipment and showing a riser pipe extending to a gathering line for delivery of produced oil to the shore;

Fig. 2 is a detailed view of the upper end of the riser pipe shown in Fig. 1 and including details of construction at the top end

and also illustrating certain aspects of the valving system at the lower end of the riser pipe;

Fig. 3 shows a pipeline pig for use with the present disclosure which is inserted into the bell nipple on the riser pipe in Fig. 2;

Fig. 4 shows an alternate embodiment of pig construction for the riser of the present disclosure;

Fig. 5 shows an abrasive strip;

Fig. 6 shows another abrasive strip;

Fig. 7 is a sectional view of the two component polymeric pig of the present disclosure shown in sectional view wherein foam donuts are spaced apart to define discs therebetween made of a harder material so that the finished product is formed of two different types of polymeric materials;

Fig. 8 is a view of a strap used in the molding process; and

Fig. 9 is an adjustable strap used in molding.

Attention is now directed to Fig. 1 of the drawings where the numeral 10 identifies an offshore platform. The platform is the tension leg type which will be explained. Briefly, it includes a drilling rig 12 which is supported on a rig floor 14. A suitable framework 16 supports the platform above the water and above the wave action. It floats on one or more buoyant tanks 18. In a sense, it is somewhat like a semi-submersible drilling rig except that it is intended to be anchored at a specific location and left at that location. For anchoring, the platform and associated equipment is tied off with

a set of tension legs 20. They function as anchor cables which extend outwardly to a remote footing 22 located on the bottom 24. The depth of the water can be typically anywhere from about 500 to about 5,000 feet. As will be understood, tension is placed in the cable which assures structural stability notwithstanding ocean currents and wave action.

The rig floor 14 must be high, and sufficiently high that wave action passes under it. The tanks 18 must be buoyant to keep the rig at the elevated position. The framework 16 must be sufficiently transparent or open so that wave action does not create large lateral forces acting against it. However, even if all this were accomplished, it would not stay on station without the use of side thrusters. It is held on station and does not move because it is tied to a particular location with the tension legs 20. They are divergent legs. In fact, there may be as many as six to twelve tension legs, some of which will be vertical and some of which will extend outwardly at an angle. They are more aptly described as anchor cables. They hold the buoyant body so that it is fixed in regard to the ocean bottom. Laterally deflecting currents and wave action do not move the platform significantly. The platform 10 is typically installed above a bottom supported template 26. The template 26 is constructed to rest on the bottom and to provide alignment for several wells. Assume as an example that the template aligns the upper ends of forty wells. It is shown in Fig. 1 at an intermediate stage, say with

most of the wells drilled, completed and connected and yet drilling continues for another well. Once the tension leg platform is on location, drilling will continue until all the wells have been completed. By the time the last well has been completed, it often is then necessary to start workover procedures on other wells. A drill string 28 drills through the template 26, and continues to the depth for the well then being drilled. Fig. 1 shows in schematic form the drill string 28 extending below while another well is being drilled. It also shows several wells 30 which have been completed at an earlier time and they are collectively all joined with a manifold 32 so that production fluid is gathered. Significantly important wellhead equipment is mounted on the template and is appropriately connected with each of the wells. Such details have been omitted to enhance clarity. The several wells 30 deliver oil and gas to the manifold 32. The manifold 32 is connected with a manifold valve 34. That valve then connects with a line valve 36. The line valve 36 connects with the gathering line 40 which extends from the offshore location.

Ignoring for the moment the fact that additional wells are being drilled, and directing attention solely to the production flow from the producing wells 30, they deliver their flow through appropriate wellhead equipment into the manifold 32 and the shoreline 40. Assume that the shoreline 40 is a sixteen inch line. Assume also that oil and gas are produced. Assume for the moment

that the production is at an elevated temperature of perhaps 200° but it is subsequently exposed to temperature stabilized water at the bottom of the sea and is cooled while flowing. If any water is produced with the oil, it also will be laden with salts. Accordingly, the shoreline 40 is likely to require pigging often. If there is any trace of H_2S in the flow, that may impact with the steel of the shoreline 40 and cause some corrosion. Also, water in the produced fluid may produce some corrosion and rust. As the temperature is dropped, the heavier molecules in the produced oil and gas may form a coating on the inside of the pipe. This coating can range from heavy paraffin or waxlike accumulations and may include mineral constituents. It can also have a striking resemblance to scale collected in water pipes, i.e., typically resembling Ca CO_3 deposits. Typically, coatings result from many reactions including corrosion of the steel making up the pipeline, paraffin or wax on the pipe and also other mineralized sediments. Preventative maintenance strongly urges that the pipeline 40 be pigged periodically so that line capacity is not lost.

If the shoreline 40 were not underwater, it would be a straightforward matter to install a pig launcher and pig trap at several locations along the line. Pigs placed in the launcher are periodically forced into the line. A pig trap is used at the remote end to catch the pigs after they travel the line. A proper pig program determines the needs and assures that pigs are introduced into the

line with adequate frequency for cleaning. In this instance, it is not possible to install a pig launcher for the shoreline 40. There is no easy way to get the pigs to the pig launcher.

The weight on the platform 10 is a limiting factor. Fig. 1 has been simplified by simply showing a drill string 28 extending through the ocean. As a practical matter, this is a simplification. Conventional drilling procedures require that the drilling be conducted through a larger pipe known as a conductor pipe. The drill pipe 28 will typically have a diameter of about four to five inches. However, such drilling is carried out through a conductor pipe which can be anywhere from about 18 inches up to about 30 inches in diameter. Of necessity, this defines a large weight which is suspended from the platform 10. The conductor pipe would otherwise resemble a tall smokestack requiring protection against lateral forces. In common practice, this pipe extends above the surface of the ocean and hangs under the platform 10. This riser pipe of substantial weight ties the platform 10 to the template and provides a large increase in platform weight. The riser just mentioned is the conductor pipe around the drill string 28. A second riser is the riser line 42 which extends to the deck 14. It is shown with a cantilevered catwalk 44 extending out to the end of it. It is off center and poses a problem in adding weight which is off center. This would otherwise tip the platform 10. This offset weight is quite substantial, and can be equal to the weight of the riser pipe

surrounding the drill string 28. Using the example of a sixteen inch shoreline 40, the riser pipe 42 is smaller and lighter than the conductor pipe around the drill string.

The riser 42 for this system is a vertical pipe. It has an upper section which is made of a specified wall thickness and then a lower section which is somewhat thicker. The thickness must be increased eventually with depth. Water pressure from the exterior increases with depth. The pressure on the exterior of the riser 42 must be resisted by the pipe construction and the pipe is therefore made stronger by using a greater wall thickness. Significantly, the riser 42 is built to an ID which is a specified ratio with respect to the pipeline 40. This reduction in diameter enables the weight of the riser 42 to be reduced significantly. The riser 42 is anchored at the lower end through its connection with the wellhead equipment located underwater. That ties the riser to the template 32 and the needed connection made for the riser is accomplished between the riser and the gathering line 40. Preferably, a valve 46 is installed in the line so that water does not accidentally enter the gathering line 40 through the riser. The riser connects with the gathering line through the valve just mentioned so that pigging operations can be controlled from the surface even through the valve is located underwater. The valve is momentarily opened to admit the pig into the gathering line. The valve, when opened, equalizes pressure from the lower end of the riser 42 and into the pipeline so that the pig is properly

pressurized to flow forwardly into the gathering line. Pressure behind the pig is momentarily increased and pressure forward of the pig is momentarily decreased so that the pig is admitted to the line 40.

The present pig 60 has a specially modified leading disc. Canting or hanging at the time of insertion into the bell is the greatest difficulty involved in pig loading and pipeline cleaning. For this, the pig is constructed with a special leading disc. As will be detailed in the description of the preferred embodiment, the leading disc is shaped so that entry is accomplished readily without canting. Should canting occur, pig insertion becomes problematic. It is even more difficult if it requires attendance of service personnel to handle the pig and reload, as it were, using an overhead hoist and hand labor. In light of the physical deployment of the riser pipe with respect to the rig platform, this may require personnel to climb out on a cantilevered catwalk located between 60 and 100 feet above the water. This may also require the personnel to handle the pig without mechanical leverage or assistance from the catwalk. It is not uncommon for a pig to weigh as much as 50 or 100 pounds depending on the number of discs and construction of the pig. With regard to the pig of the present disclosure, even in that instance, pig weight is substantial because the number of discs or cups in the pig can be increased dependent on the desired construction.

The upper end 48 of the riser (see Fig. 2) is constructed with a bell nipple 50. In effect, the nipple 50 serves as a funnel to guide and direct the pig which is dropped into it. It helps align the pig for entry into the riser. If the pig is at a canted position, entry may not be smooth. It is possible for the pig to snag at the point of entry and resist entry. The bell nipple 50 provides proper alignment of the pig. At the time of insertion of the pig into the bell nipple 50, the pig 60 is normally hoisted above the riser and dropped into the bell and is centered by the downwardly tapering wall of the bell nipple. This centering puts the pig 60 in the proper position for entry so that subsequent travel along the pipeline can be accomplished. The beginning step, however, is one that poses real problems, i.e., the pig will snag when it is canted. To avoid canting, the pig 60 is centered at the bell nipple 50 for entry into the riser. This entry enables the pig to be properly aligned and started on its travels in the riser. It falls down the riser driven by gravity. While gravity will move the pig down the riser, a hydrostatic head can be added behind the pig to force it downwardly at a greater rate. Moreover, if any hydrostatic head is added behind the pig, its downward travel can be speeded by the weight of the hydrostatic head. For instance, one barrel of liquid can be added behind the pig to add about 400 pounds of weight. As the pig falls in the riser, it may compress air below the pig. Compression of fluid at the bottom of the riser can be moderated so that the fluid does not serve as an accumulator, otherwise slowing

pig fall in the riser. A riser vent line is optionally installed so that this does not pose a problem.

The riser 42 is drawn at one scale at the upper end of Fig. 2 and is modified to a simple schematic line drawing at the bottom of Fig. 2. Again, the riser pipe 42 may be several hundred feet tall and can easily be as tall as 5,000 feet. At the bottom, there is an air vent valve 54 which enables venting of air captured under the pig 60. Indeed, as the pig falls by gravity, it will compress fluid in the riser pipe that is below it. If any sea water gets into the riser pipe 42, it is also expelled through the valve 54.

Some representative pressures will be given. In the first instance, the wells are assumed to be relatively deep because the depth of water is fairly great. Deep wells normally produce at relatively high pressures. However, wells eventually are depleted and have to be pumped, and Fig. 2 therefore includes a pump 56 which is supported on the template 32. If formation pressure is depleted, the pump delivers the oil and gas at pressure through the valve 34 and that connects with the valve 36 and delivers the pumped fluids at elevated pressure. Assume for purposes of discussion that the operating pressure in the line 40 is about 2,000 psi. The pig 60 is dropped through the riser and travels along the riser to the valve 46. The valve 46 blocks passage of the pig 60. As the pig falls, the valve 54 is opened to vent air and other fluid from the riser below the pig. Timed operation of the valve 46 enables

opening so that the pig can travel from the riser into the line 40. At the time that the valve 46 is opened, the valve 34 is preferably closed to reduce pressure in the line 40 so that the pig does not encounter a pressure resisting entry. Thus, the pig has a positive pressure drive behind it pushing it from the riser 42 through the valve 46 and into the shoreline 40. Then, the pig is launched. After it passes through the valve 46, the valve 46 is closed. By appropriate timed operation of the valves and increase of pressure from the pump 56, the pig is then driven forwardly in the line 40 for travel to shore.

Fig. 3 of the drawings shows one version of the pig 60. The pig 60 features a leading circular disc 62 of specified thickness and hardness. The disc 62 will be detailed later after review of aspects of the other disc that makes up the pig. The second layer is a foam layer 64 with a tapered outer face 66. It is bell shaped, more or less conforming to the shape of the bell nipple 50 shown in Fig. 2 of the drawings. Briefly, it is tapered so that it is able to fit into the bell nipple with the inverted position of Fig. 2 at the time of insertion. The remainder of the pig 60 is formed of several discs 68 which are equal in diameter, hardness and thickness. They are all centered around a post 70. The post 70 extends from one end to the other in the pig 60. The post also serves as an anchor for a rope eyelet 72. Similar eyelets are found at both ends for ease of handling the pig. The several discs 68 are separated by spaced donuts 74. They are

formed of softer foam. Details of the foam discs will be given below along with the harder discs.

To reduce weight and to improve sealing with the pipeline, the several donuts 74 are made of a soft foam. Typically it has a weight in the range of about three to about twelve pounds per cubic foot. One version is open cell polyurethane. It forms a wiping surface against the pipe when traveling along the line 40. The open cell structure enables liquid to flow through it. The size of the donuts should be noted. Assuming that normal operations are intended, the foam donuts 74 are sized to 100% or greater of the pig diameter. A typical range is about 102 to about 106% of the actual ID of the pipe. If the ID is sixteen inches, then the open cell foam structure is shaped to a diameter of about 16.2 to about 16.5 inches. The preferred weight is approximately five pounds per cubic foot, and the foam discs 74 are conveniently cut to a thickness of about four or five inches.

The harder discs 68 are made with a hardness of at least about 70 or 75 on the Shore A durometer scale. It can be as high as about 90. An ideal hardness is about 80 durometer. For pipes ranging from about 10 to about 20 inches in nominal measurements, the foam is about one-half inch larger in diameter than the discs 68. The central core 70 is about 1.5 inches in diameter for pipes of about 10 to 20 inch size. The several discs 68 typically have a common thickness. Typically, the thickness is about one-half inch or greater

for pipes ranging between 10 and 20 inches. The harder discs are made of cast polyurethane to the hardness noted and are made about 1% greater than the nominal ID. The foam donuts are preferably about 5% greater. This difference of about 4% represents approximately one-half inch difference between the discs 68 and donuts. The several discs 68 are therefore equal in diameter and are replicated so that there are N of these discs. In the preferred embodiment, and behind the nose disc 62, the discs 68 number typically from three to about eight. The preferred number is around four or five.

Using the construction to achieve the profile shown in Fig. 3, the pig is able to enter the bell nipple 48 easily. The pig is launched in a manner to be described but at the time of launch, it will be forced to squeeze in, thereby accommodating reductions in size. Examples of this will be noted below.

A second embodiment is identified generally at 80. It has a similar central post (on the interior and therefore not shown in fig. 4) and terminates in the same rope eyelets 82 for easy handling. It is equipped with a leading harder disc 84 and a tapered foam disc 86. Similar discs 88 are made of harder material and have dimensions that will be described. There are several foam discs between adjacent discs 88. The several foam donuts 90 are made of the same material as the foam donuts 74. Dimensions will also be given for this embodiment 80. One particular aspect of the pig 80 is the

incorporation of abrasive strips at 92. The strip 92 is an abrasive material which is applied in helical stripes. An example of this is illustrated in Fig. 5 which is a cross sectional view showing the material used to provide an abrasive strip. It has been found that carding cloth used in textile mills is quite acceptable. Carding cloth is a woven cloth belt or strap. It is typically made as shown in Fig. 5 with several layers of cloth. This provides a base of perhaps four to seven cloth layers. A U-shaped staple 94 is inserted through it. The several layers of cloth support the two points of the staple 94 in an upright position as illustrated. Other staples are driven through the cloth so that the points of the staple legs are positioned collectively as a scrapping surface. It is easy to spread over one hundred points into a square inch, and indeed, the number of points can be increased significantly above that. Because each staple is equipped with two legs and points, they are held in an upright position by the several layers of cloth. The staples and cloth construction provide an abrasive strap which is somewhere between about one and two inches in width and is embedded in the foam donut for bonding at the time of manufacture. Fig. 6 shows another form of the abrasive helical stripe 92. In this particular embodiment, the foam donut 90 is provided with a relatively thin layer of harder polyurethane. As before, the donut 90 is formed with a density of about five pounds per cubic feet therefore defining a relatively soft and pliable structure having a harder ribbon on it. The ribbon of harder

polyurethane is much denser and has a hardness approximately the same as that of the several discs 68 and 88. It is relatively thin, perhaps up to about one-quarter inch in thickness and the width is typically around one to two inches. The hard polyurethane strip is applied in a spiral or helical fashion and the outer surface during curing is used to embed tungsten carbide particles 98. The particles define sharp points which are well bonded to the body of the strip. Whether the metal points on the staples shown in Fig. 5 are used or the tungsten carbide of Fig. 6, both provide effective abrasive surfaces. In addition to that, the helical or canted installation of the strips rotate or spin to the pig. They function in the same way as does rifling in the barrel of a rifle. The helix angle is typically about 30° to 60°.

Consider now relative dimensions of the discs shown in the embodiment 80. The donuts 90 are oversized again by about one-half inch. The discs 88 are about 1% or 2% oversized. The foam donuts are larger and are preferably about one-half inch larger so that they are built to a 4% to 6% over gauge dimension. The abrasive materials are raised above the surface of the donuts 90. The staples as shown in Fig. 5 or the randomly distributed abrasive particles 98 shown in Fig. 6 are raised above the surface of the donut by a fraction of an inch, typically about 0.1 to 0.3 inches for pigs in the range of about 10 to 20 inches diameter. The donuts 90 can

otherwise resemble the donuts 74 previously discussed. The discs 88 resemble in size and hardness the discs 68.

Consider now the relative ID of the riser 42 compared with the shoreline 40. If the shoreline has an actual ID of sixteen inches, it is possible to make the discs 62 or 84 at the front or nose end of the pigs as small as twelve inches. In other words, the leading end of the pig is reduced in size by up to about 25% Using this as an outer limit, the pig preferably has a leading nose end which is about 80% of the diameter of the remainder of the body. The range can typically be about 75% or 76% at the smallest and up to about 85% at the largest. Defining the actual pipe ID as 100%, the first foam discs 64 and 86 thus have a bottom (or maximum) diameter of about 104% to about 108% at the most. These donuts 64 and 86 taper down to about 75% or 76%. Again using the same base, the discs 62 and 84 are preferably about 75% to about 85% in diameter. The hardness and thickness is common to the several discs 68 and 88. The number N for both pigs 60 and 80 are in the same range.

The pig 110 shown in Fig. 7 is a fabricated device which is made from several foam donuts 112. The foam donuts 112 are cut from a cylinder and therefore have a common diameter. More will be noted regarding that diameter in regard to a particular pipe size. The donuts 112 are preferably provided with uniform diameter, are cut at right angles, and have equal thickness. The donuts 112 are formed from foamed open cell polyurethane which is made to a very

light weight. The polyurethane foam is in the range of about 3 to about 12 pounds per cubic foot in weight. While it can be made heavier, that is more costly in that more ingredients are required and the increase in weight of the foam does not provide any particular benefit to the structure. As a cost reduction aspect, the weight of the foam is preferably lighter and is typically in the range of about 4 or 5 pounds per cubic foot. The acceptable range appears as stated but the preferred density is about 5 pounds per cubic foot.

The foam donut has a lower face 114 parallel to an upper face 116. The faces 114 and 116 are parallel and are defined by cutting. Cutting opens up the surfaces 114 and 116 so that the surface regions are porous. The significance of this will be enhanced later. The donut 112 is also drilled to form the central axial passage 118. The passage 118 is sized to a common size for all the donuts. Indeed, the pig is assembled with a number of donuts which are identical in material and external dimensions. The opening 118 defines the diameter of the core. It will be therefore described as the core diameter to distinguish from the foam outside diameter.

A single pig is made of N donuts. N is a whole number integer and is preferably in the range of 3 to 7. While it is possible to make a longer pig where N equals 8 or more, no particular gain or benefit is obtained. In like fashion, it is possible to make a pig with two such donuts but it is generally desirable for sealing purposes to utilize a longer pig, i.e., one wherein N is in the range of 3 to 7 and the

preferred values of N are 4, 5 or 6. The finished pig 110 is constructed with a smaller disc 120. The disc 120 is shown at the faces of the donut 112. The faces 114 and 116 bear against the disc 120. Again, the several discs 120 are identical and differ only in location. Since the number of donuts is given by the symbol N, there are N plus 1 of the discs 120. This enables one to be located at the leading end and one at the trailing end of the completed pig 110. The several discs 120 are preferably made of the same material and are made in a common pour so that they have the same hardness and other material characteristics.

The numeral 124 identifies the core of the pig. It is formed integral with the disc 120 and is also made at the same time. It therefore has the same material strength. The core 124 is constructed on the interior of the several donuts 112 and is confined within them by virtue of the casting process. It bonds to the donuts 112 in a fashion to be described.

Manufacturing involves molding on a flat planar surface 130. That is used to define the end face of the lowermost disc 120. The disc 120 is additionally defined by an encircling strap 132. The strap 132 is shown also in Fig. 8 of the drawings. It has the form of a hoop which is circular. It is constructed of strap material which is typically a coated steel strap or belt. At the ends, it is provided with a pair of upstanding tabs 134 which are pulled tight by connecting a nut and bolt to the tabs 134. This pulls the hoop to closure and

defines a full circle. The inside face of the strap is coated with a mold release material prior to use. The strap 132 is assembled and laid on the surface 130. It is centered with respect to the donut 112 positioned thereabove. Conveniently, the donut can be simply rested on the strap. The strap has an edge which is not sharp but is relatively narrow so that it forms an encircling dimple in the foam donut 112. The dimple represents a region of slight donut deformation. The donut 112 is rested on the strap 132 and then another strap 132 is positioned on top of it. The second strap is aligned so that it is concentric with the bottommost strap 132 and has the same diameter. Preferably again, the two straps are made to the same diameter. Another donut is then stacked on top of that strap, and the process is continued until the number of donuts in the stack is the desired number represented by N and the preferred number is 4, 5 or 6 donuts. The last strap 132 is placed at the top side of the top donut to thereby define the topmost disc. At this point, another plate similar to the plate 130 is placed over the top of the stack. This defines the exposed face of the most extreme disc. A liquid polyurethane is poured in the top and fills the assembled mold structure. The mold structure is made up primarily of the donuts 112. It includes also the N plus 1 straps 132. The urethane is poured in the core passage 118 and fills from the bottom up.

The straps 132 define the thickness of the several discs 120. The several discs 120 are poured integral with the core 124. A

suitable curing interval is permitted at which time the mold can be disassembled. Again, the mold in this particular instance is defined by the several donuts 112 and the straps, and includes the base plate 130 on which the pig is rested. Should surplus polyurethane material be poured in the mold and some leak out around any of the straps 120, it does not pose much of a problem. For instance, if the strap 132 leaks slightly above the support plate 130, a relatively small amount of leakage will typically occur because the tackiness of the polyurethane material causes it to gel and cure readily. Therefore, disassembly is easily accomplished simply by removing the parallel plates 130, and then disconnecting the straps 132. The straps 132 are opened at the tabs 134 and are then removed. This enables the straps to be saved and reused. Moreover, once all the straps are removed, the finished pig is then available. The finished pig may then be painted with appropriate colors or the like and can then be shipped.

Fig. 9 shows an alternate form of the strap 132. In this particular instance, a single strap is used for several sizes. The strap is provided with a screwdriver operated latch which engages the strap and advances it with respect to the turnbuckle 38. The end of the strap 140 is surplus strap material. By adjusting the diameter, different sizes can be made. The strap material has openings in it along the length of the strap so that the turnbuckle can engage the openings and pull the strap tight or loose. This is necessary to

change diameters. In the instance that perforations might otherwise leak, a thin sheet of paper or fiberboard is placed on the inside of the strap and can be thrown away or reused. Such a strip is shown at 142. In that sense, the paper strip 142 is a sacrificial component. It can be reused if permitted or can be discarded.

Going now to certain aspects of the present invention, it should be noted that the foam donuts 112 are cut from a larger foam cylinder. If it is desired to make a pig of 16" nominal rating, the donuts 112 are cut from an elongate cylinder of 16.2 to about 16.5" in diameter. The transverse cuts 114 and 116 cut into the open foam cell construction to define a relatively rough surface opening to the interior of the donut. The same is true of the core opening 118 which is drilled axially on the centerline. At both surfaces, the subsequently poured polyurethane material making up the end disc and core is harder and penetrates into the foam donuts to make a better bond. It is not uncommon in the casting of light polymeric materials that the mold surface causes a glossy and even slick product surface which is more or less devoid of bubbles. The slick surface has little adherence to the poured polyurethane material after setting. On cutting, the cut line intercepts a number of the interstitial openings of the foam structure. This permits some of the subsequently poured polyurethane material to penetrate into the donuts at the surfaces 114, 116 and 118 and thereby bond in a better fashion.

A heavier weight material is used for the disc 120 and the core 124. It preferably has a durometer of at least about 70 or 75 on the Shore A durometer scale. That can be as much as 90 depending on durability requirements.

The pig 110 of this disclosure is particularly able to traverse a number of pipe sizes. This will handle typical nipples and other reducers in a pipeline. Consider the following example. For a pig to be used in a nominal 12" pipe (recall that the pipe size is not precisely the I.D.), it is acceptable to make a disc 120 of the present disclosure with a diameter of 11.375". The foam donuts 112 are preferably 1/2" larger, i.e., they are 11.875". In the representative example given, the central core is about 1.5". The several discs 120 are approximately 0.375" thick. The donuts 112 are cut to a height of about 4 to about 4.5" thick. The elastomeric discs and the foam donuts flex together. They are an integral structure after the cure has been completed. They are integral in the sense that it is not possible to split them apart at the interfaces 114 and 116. Quality bonded connections are obtained. Moreover, this bonding provides an optimum pig construction for quality sealing. The several discs 120 are manufactured to approximately 1% greater than the nominal I.D. The foam donuts 112 are made about 5% larger than the pipe I.D. This speaks in particular of the nominal pipe I.D. as defined for the length of the pipeline. However, it is certainly possible that this pig will traverse a smaller opening such as a reducer or nipple which

is as much as 10 or 12% smaller in diameter. Therefore, for a 12" nominal pipe, and making the pig in accordance with the dimensions specifically given above, the pig will traverse a reducer, nipple or pipe joint which is only 10" in diameter.

Bidirectional travel is permitted. The fluid drive behind the pig causes the central portions to bulge forward while the peripheral edges of the discs 120 drag behind. Bidirectional movement is permitted and is easily started simply by pushing at the opposite end of the pig with hydraulic pressure. The pressure that drives the pig forces the discs to flip, i.e., they snap so that they bow in the opposite direction. The bowing process is accomplished for all of the discs 120 because they are joined together and they reverse simultaneously.

One aspect of the pig of this disclosure is the difference in structure of the two different types of circular elastomeric members used in the assembly of the pig. One of the two different members is the relatively hard discs built to about 1% or 2% over size in comparison with the pipe ID. By contrast, the foam donuts are quite different. The benefit of assembling the pig with alternating harder discs spaced by foam donuts is believed to derive from the relative hardness and softness of the two components. So to speak, when the pig is forced along the pipeline, drag around the peripheral edge of the hard discs deflects them around the edges. The outer edge is bent backwardly. It deflects somewhat. The central portions of the

disc are bowed forwardly. The outer edge bends to the rear, creating a curvature at the edge or lip all the way around the outer edge. When flowing in one direction in the pipe, disc bending occurs in this fashion. When the same pig flows in the opposite direction, the harder disc is bent in the other direction. Whether bent to the right or left, such bending is primarily around the outer edge. Bending of the hard disc deforms the soft foam in the adjacent donut. It is much more pliable, and has less resistance to bending. It is able to deform significantly. Yet, when free of deformation, the foam serves as a spacer which aligns the hard disc to a planar condition. Accordingly, it can be readily said that the hard discs are bent to a convex shape (the central portion is bowed forwardly) and the foam donuts conform because they are adhesively joined. Yet, some restoring force is provided so that the alternating layers forming the pig body are restored consistent with the original construction when removed from the pipeline.

The foregoing is true when the pipeline pig is input to the shoreline for which it is designed. For instance, assume the shoreline of a nominal 24 inch size is cleaned with a pig having about 1% or 2% over gauge diameter for the hard discs. One percent of 24 inches is about .24 inches. A 2% over gauge disc would therefore be about .48 inches. For pipe of that size, this is an acceptable measure of size for the disc. Typically, making the hard disc to this size makes fairly good sealing and long life.

When the pig is inserted in the bell nipple, it will collapse to a smaller diameter pipe by compressing as described above. The maximum bend is about one-third, i.e., insertion of a 24 inch pig into a riser as small as 16 inches. Compression to that amount seems to be close to the limit. While it is possible for the hard disc to snap back after greater deformation, it is possible that shear stresses introduced at the interface between the different types of material may pose a risk of damage.

Leakage around this pig is limited. In fact, the pig of the present disclosure can be used as a batch separator. The pig of this disclosure is adapted for sealing while traveling through a pipe with high quality product separation. If enhanced separation is desired, it can be obtained by mounting added hard discs on the pig body. In this instance, the number of hard discs (represented by N) can be increased from a typical short body of perhaps two or three discs up to a value of six or seven. That assures much better sealing across the pig.

When the pig of this disclosure is inserted into the riser, adding well fluid behind the pig enables enhanced pig travel down the riser with the weight of fluid on the pig. As appropriate, a single slug of an appropriate or selected liquid can be placed behind the pig. Most conveniently, the slug is a measured quantity of well fluid which is obtained from any production source in the field, for instance, oil which is obtained through production of another well from the same

platform. In all instances, the amount and nature of the fluid can be varied. The fluid is typically selected so that it will not pose a problem in mixing with the production fluids flowing in the shoreline.

As mentioned in the parent disclosure, the present pig can be formed layer by layer from the bottom. Typically, a long cylinder of shaped foam is cut to form individual donuts used in a casting process. equential fabrication from bottom to top is discussed and illustrated. That process if quite acceptable for the manufacture of the two component pigs which are set forth in this disclosure. As an alternative, a mold is used as illustrated in Fig. 4 of the drawings for casting. The mold is separated somewhat from the body of the pig 80 so that the profile of the mold can be seen. The mold 100 in Fig. 4 is constructed with a set of rings protruding inwardly. The mold is preferably rested on a flat bottom surface 102 to enable the lower end to cast to a flat surface. The donuts are cut and positioned in the mold between the rings 104. As observed, the rings extend inwardly ever so slightly to define a shoulder to prop an adjacent donut. They position the adjacent donuts parallel with a uniform open space between the donuts. The individual donuts are hollow (note the construction in Fig. 3) so that a single pour of the liquid plastic material will suffice. This forms an integral cast structure comprising the center post and the several discs. While the first disc poured is the one at the bottom, the pour is continued until each disc

fills the gap between the two adjacent donuts. The post is simultaneously and jointly cast in place.

Pouring continues until the top full scale disc 88 is in the mold. Once it has been poured, the topmost tapered donut is then positioned in the mold and the pour of the uncured liquid is continued. An interruption of a few seconds while positioning the tapered foam donut 86 in place poses no problem. It is placed in the uncured hard disc and pouring continues. A simple ring placed on the top end of the donut 86 confines lateral spread of the nose disc 84 as it is poured also. By using this approach, the several hard discs between adjacent foam donuts are formed to approximately the same diameter with good consistency, and they are formed to approximately the same thickness. Variations in disc diameter are substantially nil. Variations in thickness are less important but thickness remains fairly consistent so long as the donuts are consistently placed in the mold. The last disc 84, being smaller in diameter, is the last increment of the liquid pour. The time interval required for making the entire pour is only two or three minutes. Since the curing interval is typically many minutes, perhaps from sixty to three hundred minutes, the hard discs and the central post through the cast pig form a quality monolithic cured structure without internal flaws as a result of momentary interruptions while pouring the liquid.

Prior to pouring, it may be desirable to place an elongate nylon rope in the central donut holes. The rope is positioned so that the donuts are centered around it. The rope is then cast in the post through the pig and forms the rope eyelets 82 shown in Fig. 4. This enables easy handling of the finished pig for launching.

In one last aspect of assembly, the abrasive strips shown in Figs. 5 and 6 are assembled to the individual donuts. This preliminary assembly can be done prior to the liquid pour forming the hard discs.

As shown in Figs. 3 and 4, the narrow nose portion in inserted first and the pig therefore runs in the direction of the narrow nose. Interestingly, were it not for the problem of insertion through the riser (see example in Fig. 2), the pig can readily be inserted to run in the opposite direction. For actual pipe cleaning in the shoreline, the pigs 60 and 80 both operate bi-directionally. Because the nose portions are substantially not in contact with the sidewall of the pipe, the pig operates in a bi-directional mode. Cleaning is substantially the same when traveling in either direction. The nose that tapers to a smaller diameter in the embodiments 60 and 80 is of great advantage at the time of insertion.

While the foregoing has been directed to the preferred embodiments, the scope is determined by the claims which follow.

CLAIMS

1. A method of making a pig comprising a plurality of coaxial body discs of polymeric material, adjacent pairs of said body discs being spaced by a coaxial body torus of foamed polymeric material softer than the polymeric material of said body discs, the method comprising the steps of providing a plurality of said tori in a stack in concentric spaced relation, passing material for moulding the discs and central core through and between the tori, and allowing the moulding material to harden.

2. A method according to claim 1 wherein adjacent said tori are held in spaced relation by an annulus serving as a mould for the disc therebetween.

3. A method according to claim 2, wherein the annulus defines an internal diameter less than the diameter of the tori.

4. A method according to claim 2 or claim 3 wherein said annulus is adjustable in diameter.

5. A method according to claim 3 or claim 4 wherein said annulus comprises a steel strap or belt.

6. A method according to any preceding claim wherein the tori have porous perimeter surfaces.

7. A method according to any preceding claim wherein the tori have cut perimeter faces.

8. A method according to any preceding claim wherein the central hole of each torus is formed by drilling.

9. A method according to any preceding claim wherein the tori are formed of foamed open cell polyurethane.

10. A method according to any preceding claim wherein the density of the foamed material of the tori is between 3 and 12 pounds per cubic foot (48 to 192 kg/m^3).

11. A method according to claim 10 wherein said density is about 5 pounds per cubic foot (80 kg/m^3).

12. A method according to any preceding claim wherein each of said plurality of body discs is moulded with substantially the same first diameter.

13. A method according to claim 12 wherein a said body torus has a second diameter greater than said first diameter.

14. A method according to any preceding claim wherein each said body torus has substantially the same second diameter.

15. A method according to claim 13 or claim 14 wherein said second diameter is about 4% greater than said first diameter.

16. A method according to any preceding claim and further comprising providing external abrasive means on the perimeter faces of the tori.

17. A method according to claim 16 wherein said abrasive means comprises a cloth material, or a polymeric material having an abrasive embedded therein.

18. A method according to claim 17 wherein the cloth material has staples therein.

19. A method according to any one of claims 16 to 18 wherein the abrasive means is in the form of a belt or strip wound about the external surface of the pig.

20. A method according to any preceding claim wherein the hardness of said plurality of moulded discs is from 70 to 90 durometer on the Shore scale.

21. A method according to any preceding claim wherein there are 5, 6 or 7 said discs in said plurality.

22. A method of making a pig substantially as hereinbefore described with reference to Figures 7 to 9 of the accompanying drawings.

23. A pig formed by a method according to one of claims 1 to 22.

24. A pipeline pig comprising a plurality of coaxial discs of polymeric material, adjacent pairs of resilient discs being spaced by a coaxial torus of foamed polymeric material softer than the polymeric material of said discs.

25. A pig according to claim 23 wherein the foamed material is an open cell foam material.

26. A pig according to claim 24 or claim 25 wherein the density of the foamed material of the tori is between 3 and 12 pounds per cubic foot.

27. A pig according to claim 26 wherein said density is about 5 pounds per cubic foot.

28. A pig according to any one of claims 14 to 27 wherein each of said plurality of discs has substantially the same first diameter.

29. A pig according to claim 28 wherein a torus has a second diameter greater than said first diameter.

30. A pig according to any one of claims 14 to 29 wherein each said torus has substantially the same second diameter.

31. A pig according to claim 29 or claim 30 wherein said second diameter is about 4% greater than said first diameter.

32. A pig according to any one of claims 28 to 31 and additionally comprising a nose portion including a terminal torus adjacent an end one of said plurality of discs.

33. A pig according to claim 32 wherein said terminal torus is coaxial with said plurality of discs.

34. A pig according to claim 32 or claim 33 wherein the diameter of said terminal torus at the side remote from said end disc has a third diameter smaller than said second diameter.

35. A pig according to claim 34 wherein the diameter of said terminal torus tapers linearly or non-linearly from a fourth diameter adjacent said end disc to said third diameter.

36. A pig according to claim 35 wherein said fourth diameter is substantially equal to the second diameter.

37. A pig according to any one of claims 32 to 36 wherein said nose portion additionally comprises a terminal disc of polymeric material having a fifth diameter smaller than said first diameter and located adjacent said remote side of said terminal torus.

38. A pig according to claim 37 wherein said fifth diameter is up to 25% smaller than said first diameter.

39. A pig according to claim 37 or claim 38 as dependent on any one of claims 34 to 36 wherein said fifth diameter is less than said third diameter.

40. A pig according to any one of claims 37 to 39 wherein said terminal disc is substantially coaxial with said plurality of discs.

41. A pig according to any one of claims 14 to 40 wherein the discs are integrally moulded with a common central core on which the tori are also located.

42. A pig according to claim 41 wherein the tori are integrally joined with the integrally moulded discs and core.

43. A pig according to any one of claims 14 to 42 and further comprising external abrasive means.

44. A pig according to claim 43 wherein said abrasive means comprises a cloth material, or a polymeric material having an abrasive embedded therein.

45. A pig according to claim 43 or 44 wherein the abrasive means is in the form of a strip wound about the external surface of the pig.

46. A pig according to any preceding claim wherein the hardness of said plurality of discs is from 70 to 90 durometer on the Shore scale.

47. A pig according to any preceding claim wherein there are 5, 6 or 7 said discs in said plurality.

48. A method of making a pig as defined in any preceding claim wherein said tori are held in concentric spaced relation while material for moulding the discs and central core is passed through and between the tori and allowed to harden.

49. A method according to claim 48 wherein said tori are held in spaced relation by an annulus serving as a mould for the discs.

50. A method according to claim 49 wherein said annulus is adjustable in diameter.

51. A method according to claim 49 or claim 50 wherein said annulus comprises a steel strap or belt.

52. A method according to any one of claims 48 to 51 wherein the tori have cut annular faces.

53. A method according to any one of claims 48 to 52 wherein the central hole of each torus is formed by drilling.

54. A method of pigging a shoreline from an underwater wellhead connection to the shoreline, the method comprising the steps of:

(a) positioning a pig receiving riser provided with an insertion end above the water and coupled at a lower end for delivery of a pig into the shoreline, the insertion end having a diameter less than the diameter of the shoreline;

(b) moving a pig according to any one of claims 14 to 53 from the insertion end into the riser and then into the shoreline for travel therealong.

55. A method according to claim 54 wherein said insertion end comprises a funnel shaped bell nipple which can be opened for insertion of the pig when required.

56. A method according to claim 54 or claim 55 wherein the riser has a diameter between 75 and 85% that of the shoreline.

57. A method according to any one of claims 54 to 56 wherein the diameter of at least one of said discs of said plurality is equal to or larger than the diameter of the shoreline.

58. A method according to claim 57 wherein the diameter of said at least one disc is between 102 and 106% larger than the diameter of the shoreline.

59. A method according to claim 57 or claim 58, wherein the pig is as defined in any one of claims 32 to 40, or any one of claims 41 to 47 as dependent on claim 31, the method including the steps of inserting the nose into the insertion end and then forcing and compressing the pig body into the riser, and of dropping the pig into the shoreline

60. A method according to any one of claims 57 to 59 wherein fluid from the riser in front of the pig is removed to facilitate pig travel therealong.

61. A method according to any one of claims 53 to 60 wherein a valve is opened between the riser and the shoreline sand the pig is moved into the shoreline by application of a pressure behind the pig greater than the pressure in the shoreline.

62. A method according to claim 61 wherein the pressure in the shoreline is reduced to facilitate movement of the pig into the shoreline.

63. A method according to claim 61 or claim 62 wherein the said valve is kept closed except for passing a pig.

64. The use of a pig according to any one of claims 24 to 47 for pigging a shoreline from an offshore wellhead.

65. The use according to claim 64 wherein the well head is submarine.

66. A pipeline pig substantially as hereinbefore described with reference to Figure 7 of the accompanying drawings.

67. A method of making a pipeline pig substantially as hereinbefore described with reference to Figures 7 to 9 of the accompanying drawings.

68. A method of pigging a pipeline, using a pig according to any one of claims 24 to 47 and 66, substantially as hereinbefore described.

Amendments to the claims have been filed as follows

1. A method of making a pig comprising a plurality of coaxial body discs of polymeric material, adjacent pairs of said body discs being spaced by a coaxial body torus of foamed polymeric material softer than the polymeric material of said body discs, the discs having a diameter less than the tori, the method comprising the steps of providing a plurality of said tori in a stack in concentric spaced relation, passing material for moulding the discs and central core through and between the tori, and allowing the moulding material to harden.

2. A method according to claim 1 wherein adjacent said tori are held in spaced relation by an annulus which defines an internal diameter less than the diameter of the tori and serves as a mould for the disc therebetween.

3. A method according to claim 2 wherein said annulus is adjustable in diameter.

4. A method according to claim 2 or claim 3 wherein said annulus comprises a steel strap or belt.

5. A method according to any preceding claim wherein the tori have porous perimeter surfaces.

6. A method according to any preceding claim wherein the tori have cut perimeter faces.

7. A method according to any preceding claim wherein the central hole of each torus is formed by drilling.

8. A method according to any preceding claim wherein the tori are formed of foamed open cell polyurethane.

9. A method according to any preceding claim wherein the density of the foamed material of the tori is between 3 and 12 pounds per cubic foot (48 to 192 kg/m^3).

10. A method according to claim 9 wherein said density is about 5 pounds per cubic foot (80 kg/m^3).

11. A method according to any preceding claim wherein each of said plurality of body discs is moulded with substantially the same first diameter.

12. A method according to claim 11 wherein a said body torus has a second diameter greater than said first diameter.

13. A method according to any preceding claim wherein each said body torus has substantially the same second diameter.

14. A method according to claim 12 or claim 13 wherein said second diameter is about 4% greater than said first diameter.

15. A method according to any preceding claim and further comprising providing external abrasive means on the perimeter faces of the tori.

16. A method according to claim 15 wherein said abrasive means comprises a cloth material, or a polymeric material having an abrasive embedded therein.

17. A method according to claim 16 wherein the cloth material has staples therein.

18. A method according to any one of claims 15 to 17 wherein the abrasive means is in the form of a belt or strip wound about the external surface of the pig.

19. A method according to any preceding claim wherein the hardness of said plurality of moulded discs is from 70 to 90 durometer on the Shore scale.

20. A method according to any preceding claim wherein there are 5, 6 or 7 said discs in said plurality.

21. A method of making a pig substantially as hereinbefore described with reference to Figures 7 to 9 of the accompanying drawings.

22. A pig formed by a method according to one of claims 1 to 21.

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Application No:	GB 0110099.9	**Examiner:**	Dr Steve Chadwell
Claims searched:	1-23	**Date of search:**	14 May 2001

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UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

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Other: Online: WPI, EPODOC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X,Y	GB 1444496	(OIL STATES RUBBER) see whole document, especially page 3 lines 43-51	X: 1,2,7, 9,12,14, 16,23 Y: 10,20
Y	US 3725968	(KNAPP et al) see column 2 lines 31-34 and 48-51	10,20

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
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